# CYCLE – functional to structural to functional imaging: a feedbaCked strategY for intraCranial widEband assesments


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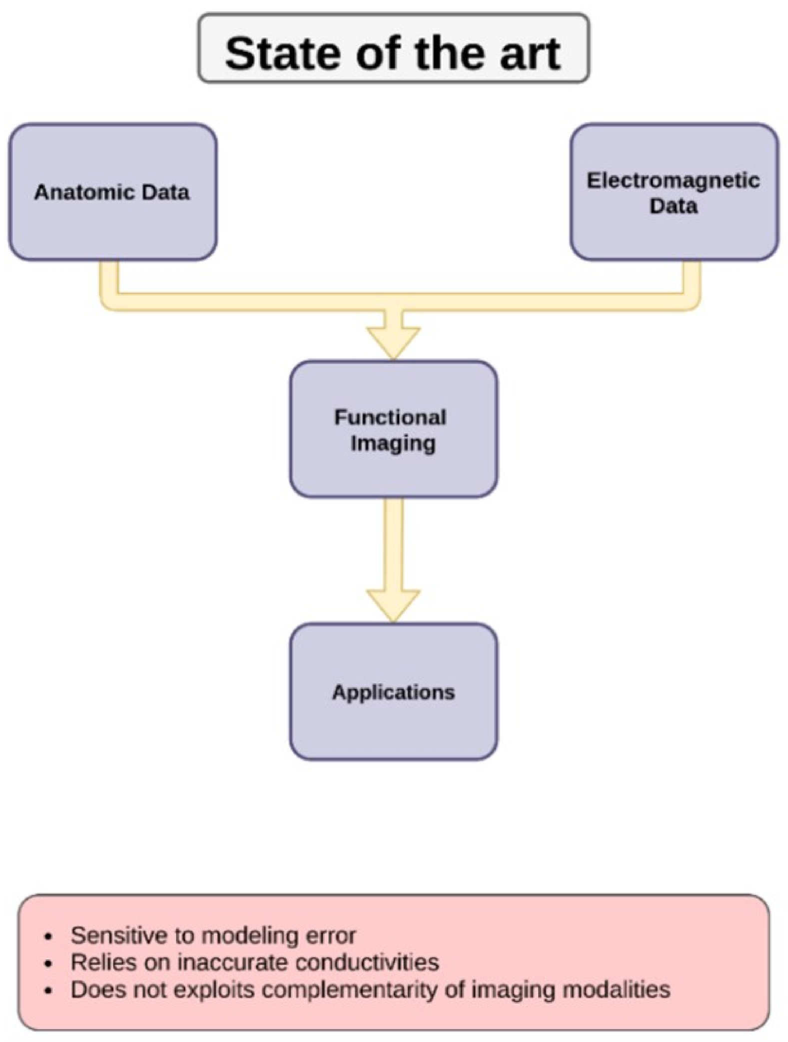
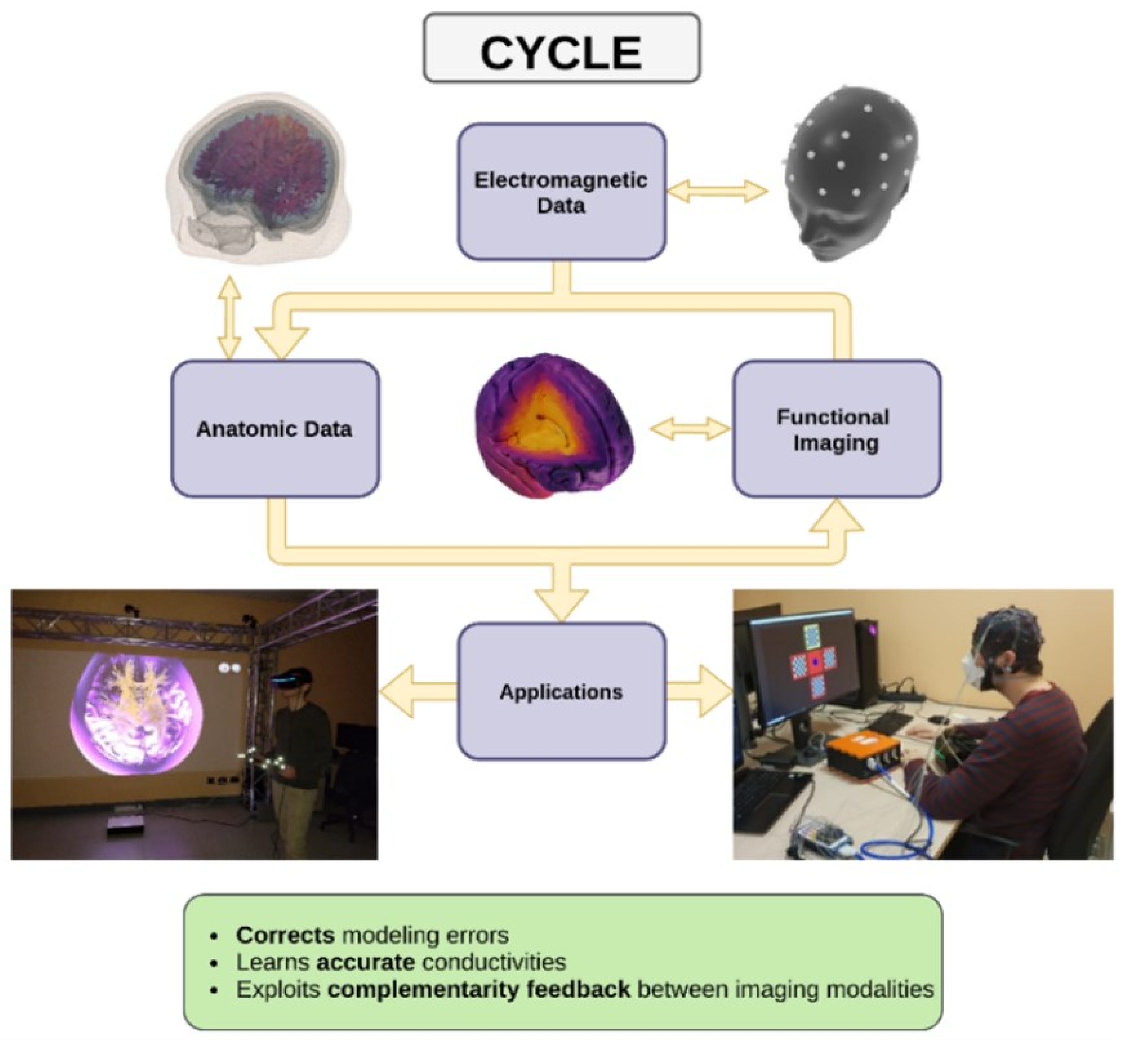
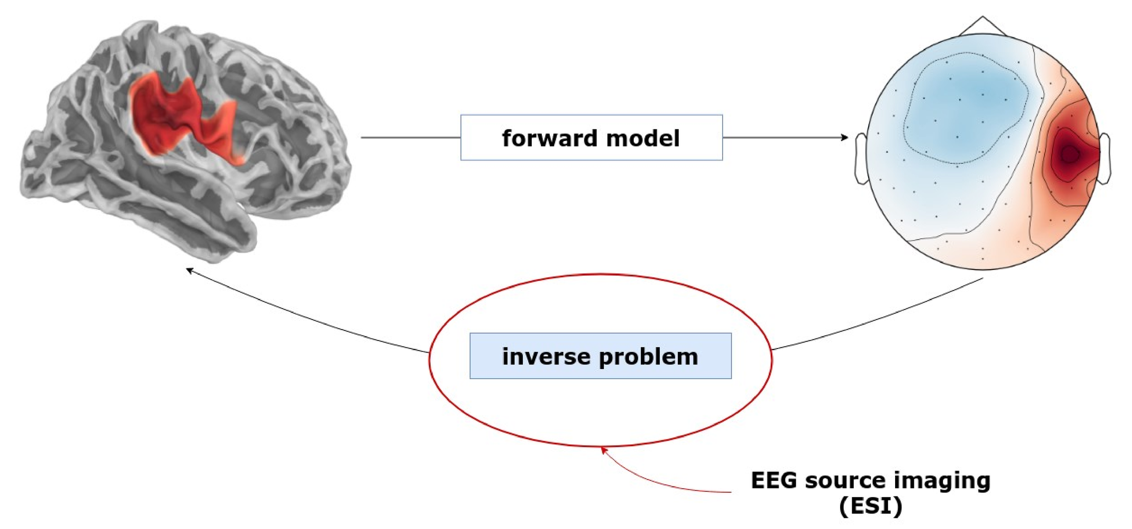
## General description




## Inverse problem in EEG




Forward model: **Y** = **LX** + **ε** (**ε** = additive noise)

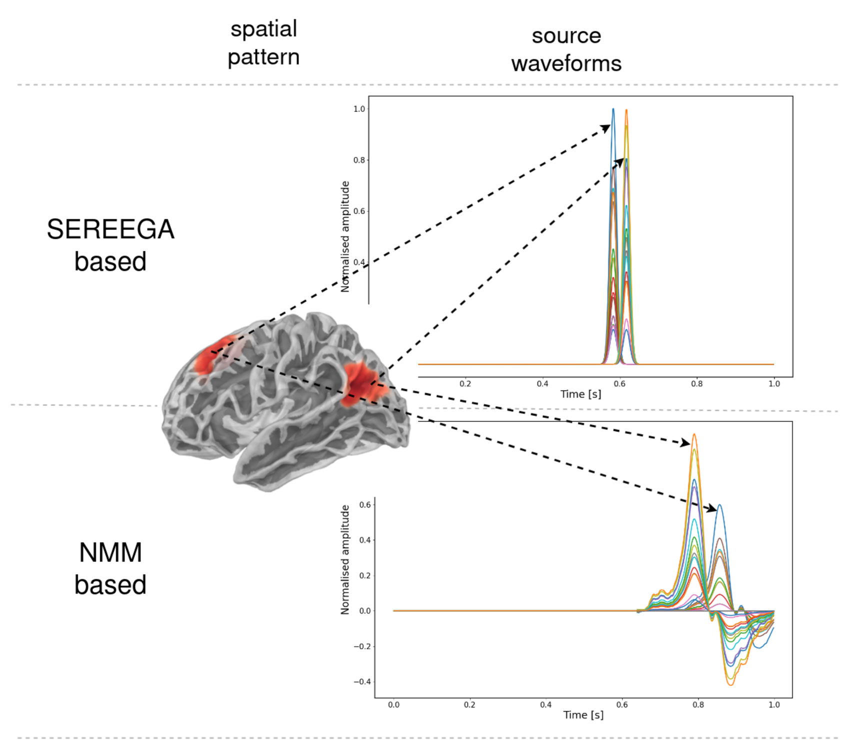
- $N_s >> N_e$: **L** non-invertible
- Volume conduction/mixing

**Ill-posed** inverse problem: add prior on **X** to solve

$$\hat{\mathbf{X}} = \underset{\mathbf{X}}{\operatorname{argmin}} \underbrace{\|\mathbf{Y}-\mathbf{LX}\|_F^2}_{\text{data fitting}} + \underbrace{\lambda R(\mathbf{X})}_{\text{prior}}$$

## Supervised learning for ESI

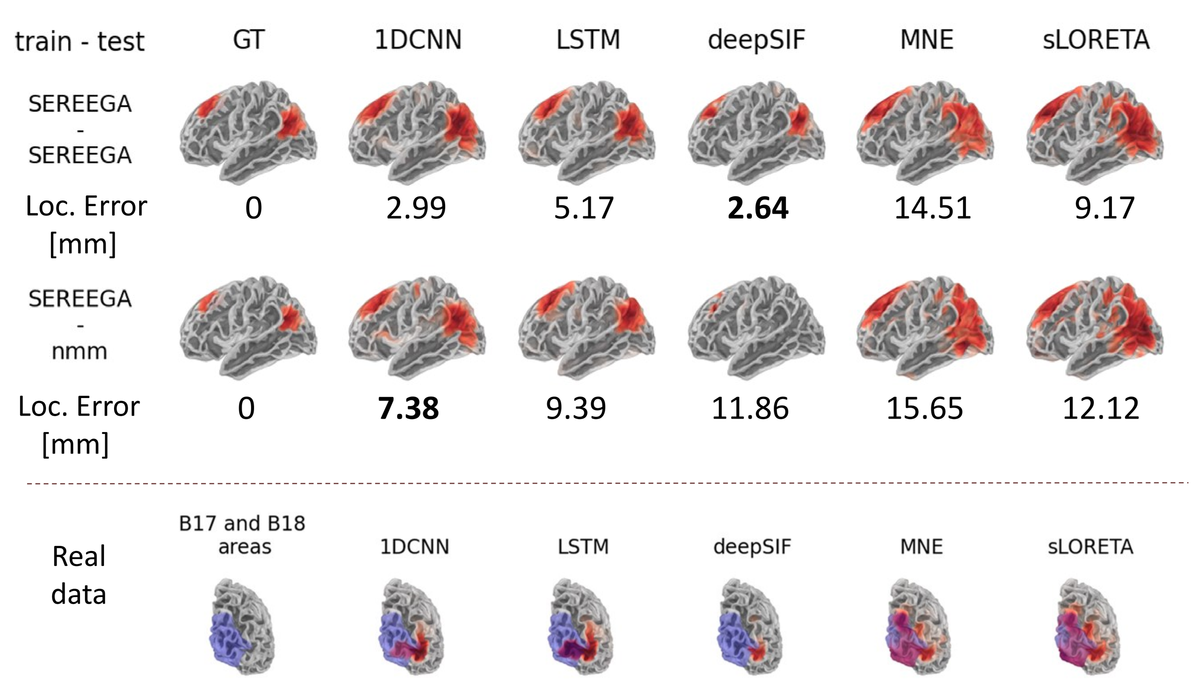
### Data simulation




*SEREEGA: Simulating Event Related EEG Activity*
*NMM = Neural Mass Model*

### Direct inversion*

3 NNs used: 1D CNN, LSTM, spatio-temporal (ResNet + LSTM)
2 simulated dataset + real data: evaluate generalization ability



| train - test | GT | 1DCNN | LSTM | deepSIF | MNE | sLORETA |
|---|---|---|---|---|---|---|
| SEREEGA - SEREEGA | | | | | | |
| Loc. Error [mm] | 0 | 2.99 | 5.17 | **2.64** | 14.51 | 9.17 |
| SEREEGA - nmm | | | | | | |
| Loc. Error [mm] | 0 | **7.38** | 9.39 | 11.86 | 15.65 | 12.12 |

| Real data | B17 and B18 areas | 1DCNN | LSTM | deepSIF | MNE | sLORETA |
|---|---|---|---|---|---|---|

*Accepted in Frontiers in Neuroscience [3]

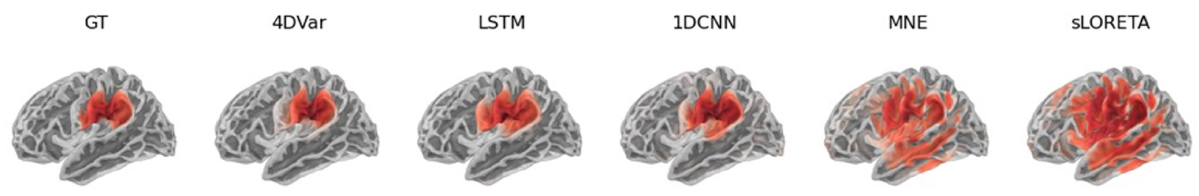
### Model based

Bi-level optimisation problem

$$\theta_\phi^*, \theta_\psi^* = \underset{\theta_\phi, \theta_\psi}{\operatorname{argmin}} \mathcal{L}(\mathbf{X}, \hat{\mathbf{X}}) \quad (O)$$

$$\text{s.t. } \hat{\mathbf{X}} = \underset{\mathbf{X}}{\operatorname{argmin}} f_o(\mathbf{Y}, \mathbf{LX}) + \lambda f_p(\mathbf{X}, \phi(\mathbf{X})) \quad (I)$$

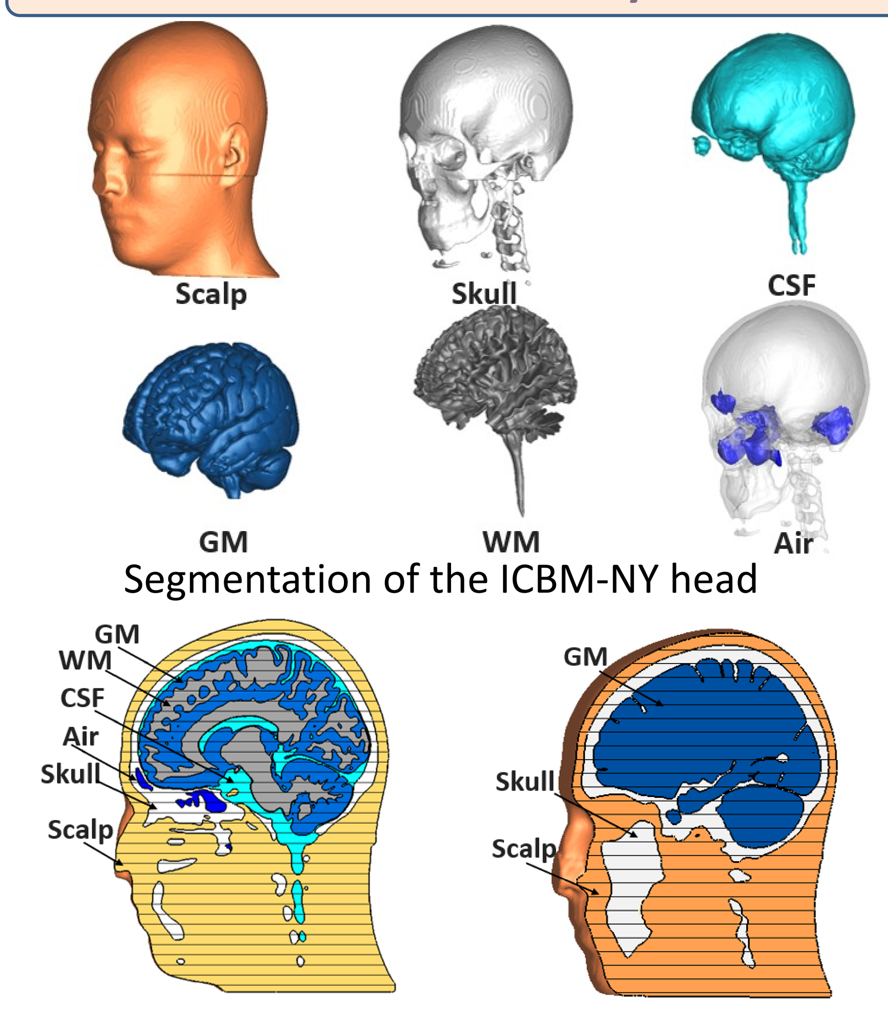
- $\theta_\phi, \theta_\psi$ : parameters of $\phi$ and $\psi$ NNs
- $f_o$, $f_p$ : discrepancy measures (e.g. $f_o(\mathbf{A},\mathbf{B}) = \|\mathbf{A}-\mathbf{B}\|_F^2$ )
- $\mathcal{L}(.,.)$ : training loss function




**First results:** performances close to direct inversion
**Future directions:**
- Many open questions → work to improve results
- Whole evalutation, test on real data

## Electromagnetic tissue-equivalent phantoms for functional brain imaging

### Head Anatomy




### Characteristics of Tissue-equivalent Mixtures

The composition of tissues

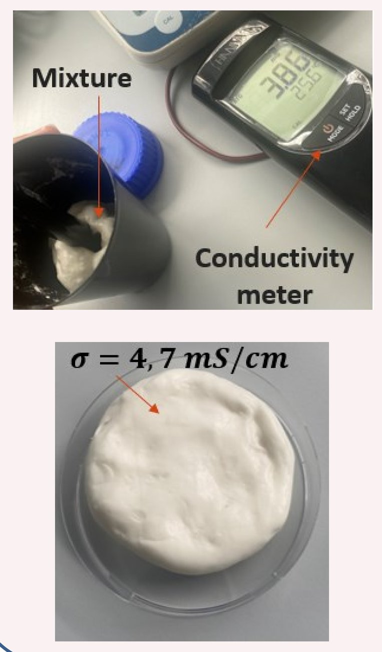
**1. GM:**
- 30g of Deionized water
- 10g of Polyethylene powder
- 4g of TX-151
- 0,06g NaCl

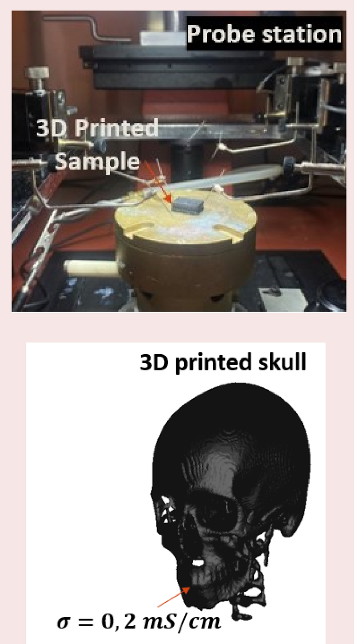
**2. Skull**
- Conductive PLA filament

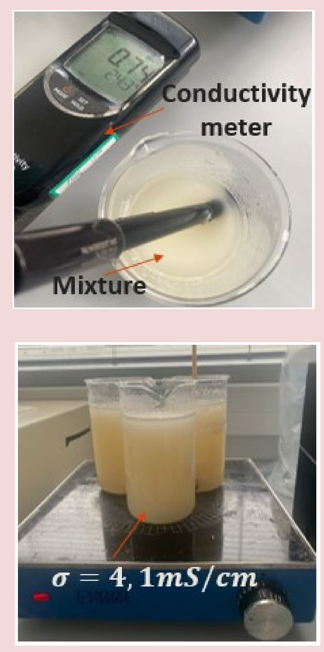
**3. Scalp**
- 4g of Agar
- 1,1g NaCl
- 550g of Deionized water

Conductivity measurement setup

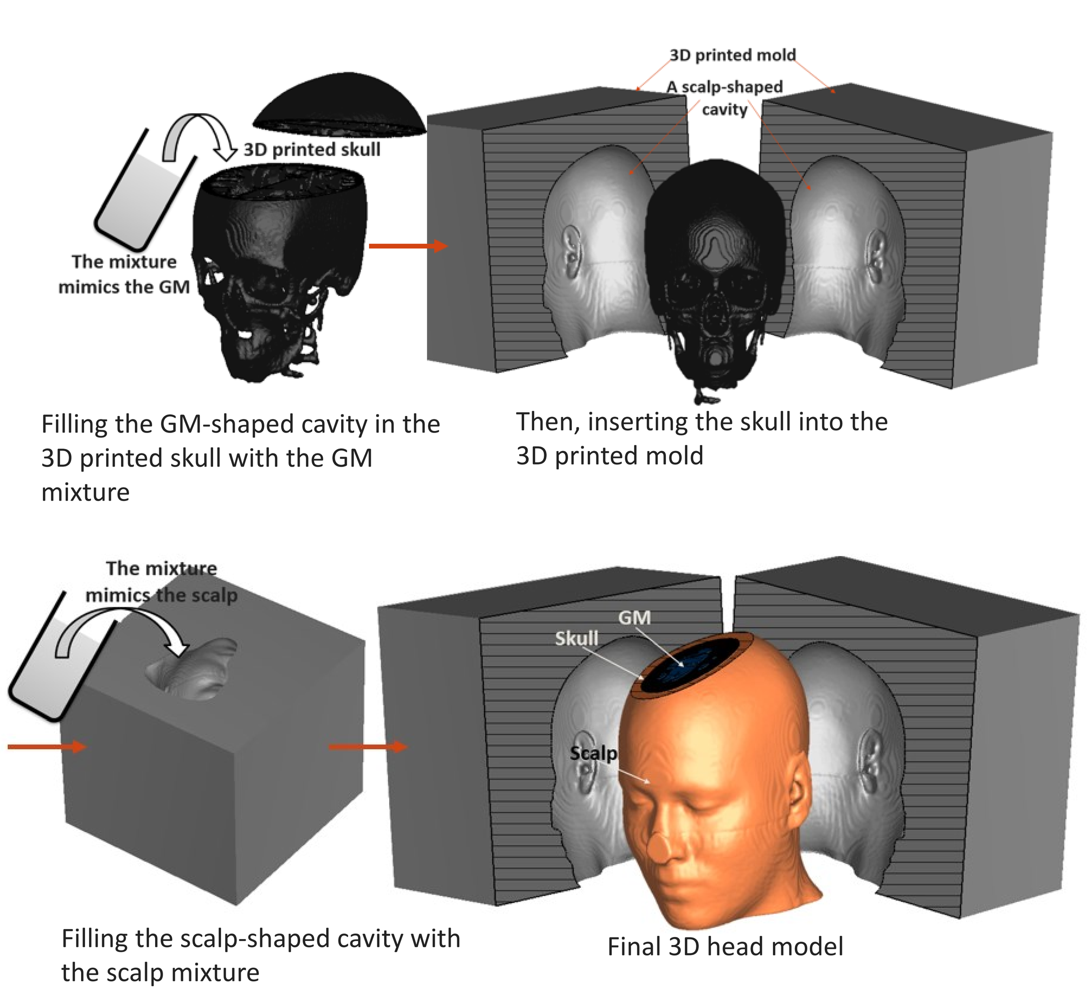
Tissue-equivalent Mixture




### Prototyping




## Publications


1. **V. Giunzioni *et al.*, *IEEE Trans. Antennas Propagat.*, submit.**
2. **R Chen *et al.*, *IEEE Trans. Antennas Propagat.*, in rev.**
3. **S. Reynaud *et al.*, Frontiers in Neuroscience, 2024.**
4. R. Chen *et al.*, ACES-China, 2024.
5. A. Scazzola *et al.*, AP-S/INC-USNC-URSI, 2024
6. S. Reynaud *et al.*, EUSIPCO 2023.
7. A. Merlini *et al.*, EMTS 2023.
8. **A. Merlini *et al.*, *IEEE Trans. Antennas Propagat.*, 2023.**
9. A. Merlini *et al.*, ICEAA 2023.
10. C. Henry *et al.*, IEEE CAMA 2023.
11. C. Henry *et al.*, *EuCAP* 2023.
12. **V. Giunzioni *et al.*, *Journal of Comput. Physics*, 491, 2023.**
13. V. Giunzioni *et al.*, IEEE CAMA 2023.
14. **C. Henry *et al.*, *IEEE Trans. Antennas Propagat.*, 2022.**
15. C. Henry *et al.*, AP-S/USNC-URSI 2022.
16. C. Henry *et al.*, CAMA 2022.
17. D. Consoli *et al.*, *ICEAA* 2022.
18. C. Henry *et al.*, URSI GASS 2021.
19. **S. B. Adrian *et al.*, *IEEE Open J. Antennas Propag.*, 2, 2021.**